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Difficulty of Elderly SCI Subjects to Translate Motor Recovery—"Body Function"—into Daily Living Activities

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Abstract

The objective of this retrospective analysis was to determine whether outcome of body functions and activities as well as length of stay of inpatient rehabilitation is related to age in patients with traumatic spinal cord injury (SCI). Data were collected from a European network of 17 SCI rehabilitation centers (EM-SCI); a total of 237 traumatic SCI subjects were included. Assessments were performed at 1, 6, and 12 months after SCI. The measures analyzed were motor score according to the American Spinal Injury Association, Spinal Cord Independence Measure (SCIM), gait speed, and length of stay. Correlation analysis was applied to quantify the association between age and change in the outcome measures. A positive relationship was found between age and neurological recovery in both the first and second 6-month periods of assessment. A negative relationship was found between age and change in SCIM in the second 6-month period after SCI. A negative relationship between age and gait speed was observed in the first half year. Length of stay was not associated with age. It was concluded that age is an important determining factor for functional outcome after SCI and that elderly patients have difficulties in translating an improvement in neurological outcome into functional changes. Therefore, rehabilitation approaches in elderly subjects should focus on functional training.

Key words: aged; spinal cord injuries (SCI); treatment outcome

Introduction

THE PREVALENCE OF SPINAL CORD INJURY (SCI) has increased over the past 20 years (O'Connor, 2005). The main reasons for this are age-specific SCI incidences, reduced mortality rates (DeVivo, 1999, 2007), and aging of the population. Therefore it can be expected that the proportion of elderly patients experiencing an acute SCI will increase in the future. This is already the case in the United States, where the mean age at SCI increased from 29 to 38 years during the past three decades (DeVivo, 2007; Jackson et al., 2004). Public payers and insurance companies claim that outcome and costs should be in a favorable balance for all age groups (Cruise et al., 2006). If this is not the case, age-adapted rehabilitation plans should be established.

According to the framework of the International Classification of Functioning, Disability and Health (ICF), comprehensive rehabilitation after SCI aims to improve body functions and daily life activities in order to advocate social participation (Stucki et al., 2007; World Health Organization, 2001). Correspondingly, measures of rehabilitation outcome should address body functions and activities/participation.

There have been several studies in the past two decades that deal with the influence of age on the recovery of daily life activities and neurological outcome (body function) and on the duration of inpatient rehabilitation. However, the findings are inconsistent. Some studies describe a significantly better improvement for younger patients: in a matched cohort of traumatic and non-traumatic SCI subjects, younger patients had a better functional and neurological rehabilitation outcome (Scivoletto et al., 2003). However, the length of stay for inpatient rehabilitation was shorter in the group of older patients. Another report (McKinley et al., 2003) summarized the results from previous studies (Cifu et al., 1999a, 1999b, 1999c; Seel et al., 2001) and claimed that age has three effects on outcome in traumatic SCI subjects: (1) patients with paraplegia have a longer duration of in-patient rehabilitation, (2) patients with tetraplegia show little change in neurological recovery and, (3) patients with SCI have less change in functional outcome. In a recent study of patients with traumatic central cord injury, a shorter length of stay in older patients and a negative relationship between age and neurological or functional outcome were described (Aito et al., 2007). In contrast, according to a study on a large population of traumatic SCI subjects, elderly patients stayed longer in the rehabilitation facility (Eastwood et al., 1999) or, according to several other studies, no influence of age on outcome and length of rehabilitation stay was found (Furlan et al., 2008a;

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Kennedy et al., 2003; Pentland et al., 1995; Ronen et al., 2004; Yarkony et al., 1988).

The findings reported over the past 20 years are inconsistent. However, although most authors propose a relationship between age and outcome, stronger predictors for outcome seem to be injury characteristics (e.g., level and completeness of injury). The age effect seems to vary between subgroups of SCI patients (McKinley et al., 2003). Some of the previous studies are limited because of a small sample size (Pentland et al., 1995; Scivoletto et al., 2003; Yarkony et al., 1988), a single center approach (Scivoletto et al., 2003), variations in timing of examinations (Cifu et al., 1999a, 1999b, 1999c; Kennedy et al., 2003; Pentland et al., 1995; Scivoletto et al., 2003; Seel et al., 2001), or only a subset of traumatic SCI was considered (Aito et al., 2007).

The aim of this study was to evaluate whether age of traumatic SCI subjects has an effect on daily life activities and neurological outcome within the first year after injury and the duration of inpatient rehabilitation. We hypothesize that (1) there is a negative effect of age on both outcome of neurological deficit and limitation of daily life activity, and (2) older patients, on average, undergo longer inpatient rehabilitation.

Materials and Methods

Data were obtained from the database of the European Multicenter Study of Human Spinal Cord Injury (EM-SCI) (Curt et al., 2004). EM-SCI is a network of 17 European rehabilitation centers that was started in 2001. The aim of the network is to standardize the assessments of SCI patients over time. The assessments included a clinical neurological examination, according to the standards of the American Spinal Injury Association (ASIA, 2002; Marino et al., 2003), using an ASIA impairment scale and ASIA motor and sensory scores, the Spinal Cord Independence Measure (SCIM) (Catz and Itzkovich, 2007), walking tests (van Hedel et al., 2005) and neurophysiological recordings (Spiess et al., 2008). The patients were initially assessed within the first 2 weeks (i.e., as soon as possible after injury) and then after 1, 3, 6, and 12 months after the onset of the SCI. All recordings were stored anonymously in a central database, which contained data of 1180 SCI subjects at the time of this study.

Subjects

Subjects with traumatic or ischemic paraplegia or tetraplegia after a single event were included in the EM-SCI database. All subjects were capable and willing to give written informed consent and were assessed at least within 6 weeks after incidence. Patients with peripheral nerve lesions above the level of lesion, pre-existing polyneuropathy, or cerebral injury were not included in the EM-SCI database.

A subset of the EM-SCI database was included in this study. Specifically, all patients older than 18 years, who suffered a traumatic SCI and who were rehabilitated between July 2001 and June 2007 with a complete data record for the examinations at 1, 6, and 12 months after the injury were included in this study.

Measurements

The variables analyzed were sex, age, level of lesion (paraplegia/tetraplegia), ASIA Impairment Scale (AIS), ASIA motor score, SCIM, gait speed assessed using the 10 meter walk test (10MWT), and length of stay for primary inpatient rehabilitation. Prior to further analysis the records were checked for plausibility. The values were checked whether they were in the expected range or whether they agreed with each other, that is, if the neurological level of injury corresponded to the result of the ASIA examination.

Neurological recovery

In concordance with previous studies (McKinley et al., 2003; Scivoletto et al., 2003), we used the ASIA motor score (Maynard et al., 1997) to record the neurological recovery, although it is only slightly sensitive for thoracic lesions (due to the fact that no muscles are tested that are innervated by thoracic segments) (van Hedel and Curt, 2006). Nevertheless, in a recent systematic review (Furlan et al., 2008b), it was reported that good reliability and construct validity exist for the ASIA Standard Classification for adults with traumatic SCI.

Functional recovery

We used the SCIM (Catz and Itzkovich, 2007) as the main rating scale for functional outcome. The SCIM reliably and validly rates activities of daily life and independence according to their importance for the patient. In the EM-SCI network the revised version (Catz et al., 2001; Itzkovich et al., 2003; Itzkovich et al., 2002) was used. To examine mobility, the 10MWT was used because validity, reliability, and responsiveness of this test have been proven previously (van Hedel et al., 2005, 2006). The time needed to perform the 10MWT was converted into gait speed (in m/s). For patients who were unable to walk, gait speed was set to 0 m/s.

Patient categorization

The analysis was performed for the sample as a whole as well as for subgroups to investigate the interaction between age and severity of the SCI. Patients were categorized into subgroups based on the examination at 1 month after SCI. The analysis was performed at three levels: on the first level, all patients were included; on the second, the two groups (paraplegia and tetraplegia) were formed; and on the third, a further subgrouping for the paraplegia and tetraplegia patient groups was made into "motor complete" and "motor incomplete."

Statistical analysis

Descriptive statistics were used to characterize the sample. For ASIA motor scores, SCIM, and gait speed, the differences between examinations at 1 and 6 months and at 6 and 12 months were calculated, respectively. ASIA motor scores and SCIM are sums of ordinal numbers; however, since we used only total scores, we considered them as proportional (interval-scaled) numbers.

In order to evaluate whether age was associated with the outcome measures (i.e., changes in ASIA motor score, SCIM, gait speed, and length of stay), Pearson's correlations were applied.

A sample size calculation for paraplegic and tetraplegic subjects was performed on the basis of the distributions of the primary outcome (i.e., SCIM). For this we applied a formula for paired means. The level for statistical significance was set at 0.05. We used SPSS, version 15 (SPSS, Inc., Chicago, IL), to calculate the correlations.

Results

The EM-SCI database at the time of the study contained 1182 SCI subjects in total. Of this group, 432 patients did not meet the inclusion criteria (42 were not eligible due to their young age, 308 were rehabilitated earlier or later than the specified range, 80 had etiology that was non-traumatic, and two datasets were erroneous). From the remaining 750 patients who were eligible, 513 subjects could not be analyzed due to incomplete or incorrect records for at least one of the three examinations (1, 6, or 12 months after the incident). Thus, a sample consisting of 237 patients was analyzed in this study. We performed a comparison of the 513 patients with the 237 who were included regarding age and the distribution of sex, motor completeness, and neurological level of injury (i.e., paraplegia or tetraplegia). The comparison revealed that the groups were different pertaining to age and motor completeness. Patients whose data could not be analyzed were older (46.2 vs. 42 years, $p = 0.001$), and the proportion of motor incomplete SCI was greater (50% vs. 39%, $p = 0.006$).

Sample characteristics

Table 1 shows the characteristics of the whole sample and its subgroups. The mean age in the whole sample was 42 (±standard deviation [SD] 17) years. Among the subgroups the age ranged between 39 (±SD 15) and 50 (±SD 17) years, "motor incomplete tetraplegia" being the subgroup with the highest average age.

At the 1-month examination after SCI the ASIA motor score, SCIM and gait speed were lower for tetraplegic compared to paraplegic subjects and, within both groups, for motor complete compared to motor incomplete subgroups. The length of inpatient rehabilitation was longer. In general, the improvement was also lower for tetraplegic and motor complete subjects. However, there were exceptions: (1) the improvement in ASIA motor score was greater in tetraplegic compared to paraplegic subjects; and (2) the improvement in SCIM did not differ between para- and tetraplegic subjects in the second half year. In addition, the change in gait speed was similar in para- and tetraplegic subjects over the whole year of analysis. For the total sample, the functional and neurological outcome continued to improve in the second half year after SCI, but at a smaller rate. The ASIA motor score improved in the second half year by 30%, the SCIM by 11%, and gait speed by 28% in relation to the improvement during the first 6 months.

Correlations between age and outcome measures

Table 2 shows the correlations between age and outcome measures and Figure 1 illustrates the main findings.

Age and ASIA motor score

For the whole sample, the change in ASIA motor score was positively related to age; older patients showed a greater improvement in ASIA motor score during both time periods (between first and sixth month: 0.178, $p < 0.01$; between sixth and twelfth month: 0.226, $p < 0.001$). The motor score was not

Table 1. Characteristics of Sample Population

	Paraplegia		*Tetraplegia*				
Group	*mc*	*mi*	*mc*	*mi*	*Para*	*Tetra*	*All*
Number	87	39	58	53	126	111	237
Women (%)	20	21	26	11	20	19	19
Age	38.5 ± 15.5 (37)	41.3 ± 16.5 (38)	40.3 ± 17.5 (35.5)	50.0 ± 17.3 (51)	39.3 ± 15.8 (37)	44.9 ± 18.0 (43)	41.9 ± 17.0 (39)
Min-max	18–94	19–84	18–72	20–76	18–94	18–76	18–94
*MS*baseline	51.4 ± 4.7 (50)	76.9 ± 14.5 (77)	18.4 ± 15.8 (15)	56.3 ± 25.7 (57)	59.3 ± 14.8 (50)	36.5 ± 28.3 (32)	48.6 ± 24.9 (50)
$\Delta_{(1-6)}$MS	2.9 ± 5.7 (0)	8.3 ± 7.2 (7)	8.1 ± 10.9 (5.5)	19.1 ± 14.8 (18)	4.5 ± 6.6 (0)	13.3 ± 14.0 (9)	8.7 ± 11.6 (4)
$\Delta_{(6-12)}$MS	0.9 ± 2.7 (0)	3.0 ± 4.4 (3)	2.7 ± 6.1 (1)	5.2 ± 6.9 (4)	1.6 ± 3.4 (0)	3.9 ± 6.6 (3)	2.6 ± 5.3 (1)
SCIM baseline	31.6 ± 13.7 (31)	53.3 ± 23.1 (56)	13.4 ± 8.3 (14)	33.1 ± 26.2 (25)	38.2 ± 19.8 (34)	22.8 ± 21.4 (15)	31.0 ± 21.9 (27)
$\Delta_{(1-6)}$SCIM	32.7 ± 15.0 (37)	33.4 ± 16.2 (35)	19.2 ± 13.8 (16)	38.4 ± 21.8 (37)	32.9 ± 15.4 (36.5)	28.4 ± 20.4 (23)	30.8 ± 18.0 (32)
$\Delta_{(6-12)}$SCIM	4.0 ± 8.4 (3)	0.9 ± 5.6 (0)	1.8 ± 5.1 (1)	6.0 ± 11.1 (1)	3.1 ± 7.7 (1)	3.8 ± 8.7 (1)	3.4 ± 8.2 (1)
Gait speed baseline	0.001 ± 0.012 (0.00)	0.273 ± 0.424 (0.00)	0.000 ± 0.000 (0.00)	0.222 ± 0.438 (0.00)	0.085 ± 0.266 (0.00)	0.106 ± 0.321 (0.00)	0.095 ± 0.293 (0.00)
Unable to walk	86 98.9%	25 64.1%	58 100%	39 73.6%	111 88.1%	97 87.4%	208 87.8%
$\Delta_{(1-6)}$ gait speed	0.045 ± 0.176 (0.00)	0.620 ± 0.509 (0.62)	0.000 ± 0.000 (0.00)	0.570 ± 0.567 (0.42)	0.223 ± 0.414 (0.00)	0.272 ± 0.484 (0.00)	0.246 ± 0.448(0.00)
$\Delta_{(6-12)}$ gait speed	0.030 ± 0.132 (0.00)	0.156 ± 0.283 (0.10)	0.002 ± 0.012 (0.00)	0.139 ± 0.269 (0.06)	0.069 ± 0.200 (0.00)	0.067 ± 0.197 (0.00)	0.068 ± 0.198 (0.00)
LOS	168.9 ± 74.2 (149)	93.0 ± 55.6 (86)	208.4 ± 67.4 (195.5)	143.1 ± 76.0 (134)	145.7 ± 77.3 (135.5)	177.3 ± 78.5 (170)	160.3 ± 79.3 (149)
Min-max	41–452	21–266	96–430	16–359	21–452	16–430	16–452

AIS, ASIA Impairment Scale; LOS, length of stay; MS, ASIA motor score; SCIM, Spinal Cord Independence Measure; mc, motor complete; mi, motor incomplete. Gait speed was measured in m/s using the 10 meter walk test. Baseline, variable measured 1 month after injury; $\Delta_{(1-6)}$, change between 1 and 6 months after injury. $\Delta_{(6-12)}$, change between 6 and 12 months after injury. Unless otherwise specified, values are presented as mean ± standard deviation with median in parentheses.

Table 2. Correlations between Age and Outcome Measures

Group (n)	Paraplegia mc (87)	Paraplegia mi (39)	Tetraplegia mc (58)	Tetraplegia mi (53)	Para (126)	Tetra (111)	All (237)
ASIA motor score At 1 month after injury	.113 (.299)	**−.339 (.035)**	**.358 (.006)**	−.001 (.995)	−.015 (.871)	**.281 (.003)**	.079 (.227)
Change between first and sixth month after injury	−.159 (.142)	.026 (.877)	.216 (.104)	.057 (.687)	−.051 (.573)	**.219 (.021)**	**.178 (.006)**
At 6 months after injury	−.045 (.682)	**−.360 (.024)**	**.435 (.001)**	.041 (.770)	−.032 (.725)	**.356 (<.001)**	**.157 (.016)**
Change between sixth and twelfth month after injury	.047 (.666)	**.558 (<.001)**	.188 (.157)	.060 (.669)	**.275 (.002)**	.167 (.080)	**.226 (<.001)**
At twelve months after injury	−.025 (.817)	−.184 (.261)	**.453 (<.001)**	.066 (.640)	.021 (.815)	**.376 (<.001)**	**.197 (.002)**
SCIM At 1 month after injury	−.160 (.138)	**−.579 (<.001)**	**−.297 (.024)**	−.058 (.678)	**−.247 (.005)**	.034 (.720)	**−.151 (.020)**
Change between first and sixth month after injury	**−.249 (.020)**	.213 (.193)	.051 (.701)	**−.321 (.019)**	−.091 (.313)	−.011 (.912)	−.064 (.324)
At 6 months after injury	**−.409 (<.001)**	**−.544 (<.001)**	−.099 (.459)	**−.308 (.025)**	**−.335 (<.001)**	.017 (.857)	**−.168 (.010)**
Change between sixth and twelfth month after injury	**−.304 (.004)**	−.184 (.262)	−.105 (.432)	−.128 (.360)	**−.279 (.002)**	−.039 (.684)	**−.142 (.028)**
At twelve months after injury	**−.606 (<.001)**	**−.558 (<.001)**	−.121 (.365)	**−.372 (.006)**	**−.464 (<.001)**	.006 (.953)	**−.208 (.001)**
Gait speed At 1 month after injury	.186 (.084)	−.266 (.102)	–	.172 (.217)	−.089 (.319)	**.201 (.035)**	.074 (.255)
Change between first and sixth month after injury	−.019 (.859)	**−.382 (.016)**	–	**−.347 (.011)**	−.101 (.259)	−.025 (.795)	−.050 (.442)
At 6 months after injury	−.006 (.958)	**−.478 (.002)**	–	−.169 (.225)	−.120 (.183)	.083 (.387)	−.001 (.985)
Change between sixth and twelfth month after injury	−.087 (.422)	−.135 (.413)	.051 (.702)	−.043 (.760)	−.075 (.402)	.069 (.471)	−.004 (.950)
At twelve months after injury	−.057 (.599)	**−.525 (.001)**	.051 (.702)	−.194 (.164)	−.133 (.138)	.100 (.297)	−.002 (.972)
Length of stay (days)	−.042 (.698)	.292 (.071)	−.044 (.741)	.056 (.693)	.002 (.986)	−.108 (.261)	−.019 (.772)

The Pearson correlation method was used. The first number for each group represents the correlation coefficient, which quantifies the relationship between age difference (in years) and the outcome measures. These were the ASIA motor score, the SCIM, and gait speed (using the 10 meter walk test) at the examinations after the first, sixth, and twelfth month after injury and the changes of these measures between the three examination times. A fourth outcome variable was the length of stay (number of days spent in a rehabilitation center). The number in parentheses represents the p value. Groups for which the outcome variable was significantly related to age ($p < 0.05$) are in bold. In the group "motor complete tetraplegia," the Pearson correlation between age and gait speed at 1 and 6 months after injury (and as a consequence the change between these two examination times) could not be calculated since the gait speed for all 58 patients was 0 m/s.

related to age at 1 month, but it was related to age at 6 months (0.157, $p < 0.05$) and 12 months (0.197, $p < 0.01$). Concerning the subgroups, we found a positive relationship in the second half year for paraplegia (0.275, $p < 0.01$) and motor incomplete paraplegia (0.558, $p < 0.001$). For the first half year, a positive relationship was obtained for tetraplegia (0.219, $p < 0.05$).

Age and SCIM

The sample size calculation for the SCIM showed that for paraplegic and tetraplegic subjects 2.4 and 4.8 pairs of observations would be sufficient to reach statistical significance. For the whole sample, age was negatively associated with the change in SCIM between the sixth and twelfth month after injury (-0.142, $p < 0.05$). In the second half year, the average patient improved by 3.4 SCIM points. For the same time period, a regression analysis showed that 40 years of age difference amounted to 2.8 SCIM points less improvement. At all three examination times, SCIM was negatively related to age (at 1 month after injury: -0.151, $p < 0.05$; 6 months: -0.168, $p < 0.01$; 12 months: -0.208, $p < 0.001$).

For the subgroups we found a negative relationship between age and change in SCIM for paraplegic subjects in the second half year (-0.279, $p < 0.01$), for patients with motor complete paraplegia in the first (-0.249, $p < 0.05$) and second (-0.304, $p < 0.01$) half year, and for patients with motor incomplete tetraplegia in the first half year (-0.321, $p < 0.05$). Consequently older patients improved less in SCIM during the whole observation period or even deteriorated (Fig. 1).

Age and gait speed

No relationship between age and changes in gait speed was found at the 1-month stage. However, a negative correlation was found for motor incomplete groups at 6 months (-0.382 for paraplegia, -0.347 for tetraplegia, $p < 0.05$), suggesting that age negatively influences gait speed during the first half year. For the group of motor complete tetraplegic subjects, no correlation coefficient could be calculated because none of these patients became ambulatory (gait speed remained zero).

Age and length of stay

Length of stay was not related to age, neither in the whole sample nor in any of the subgroups.

Discussion

The aim of this study was to evaluate whether age has an effect on the changes in neurological and functional outcomes and length of stay in patients within the first year after an acute SCI. The effect of age seems to depend on (1) the subgroup of SCI subjects (level, severity), (2) the outcome measure under study, and (3) the time period after SCI. The following age effects were found:

1. A positive relationship with respect to the outcome of neurological deficit (ASIA motor score) within the first year;
2. A negative relationship with respect to the outcome in daily life activity (SCIM), especially in the second half year (and within the group of patients with paraplegia);
3. A negative relationship with gait speed in patients with motor incomplete SCI during the first half year.

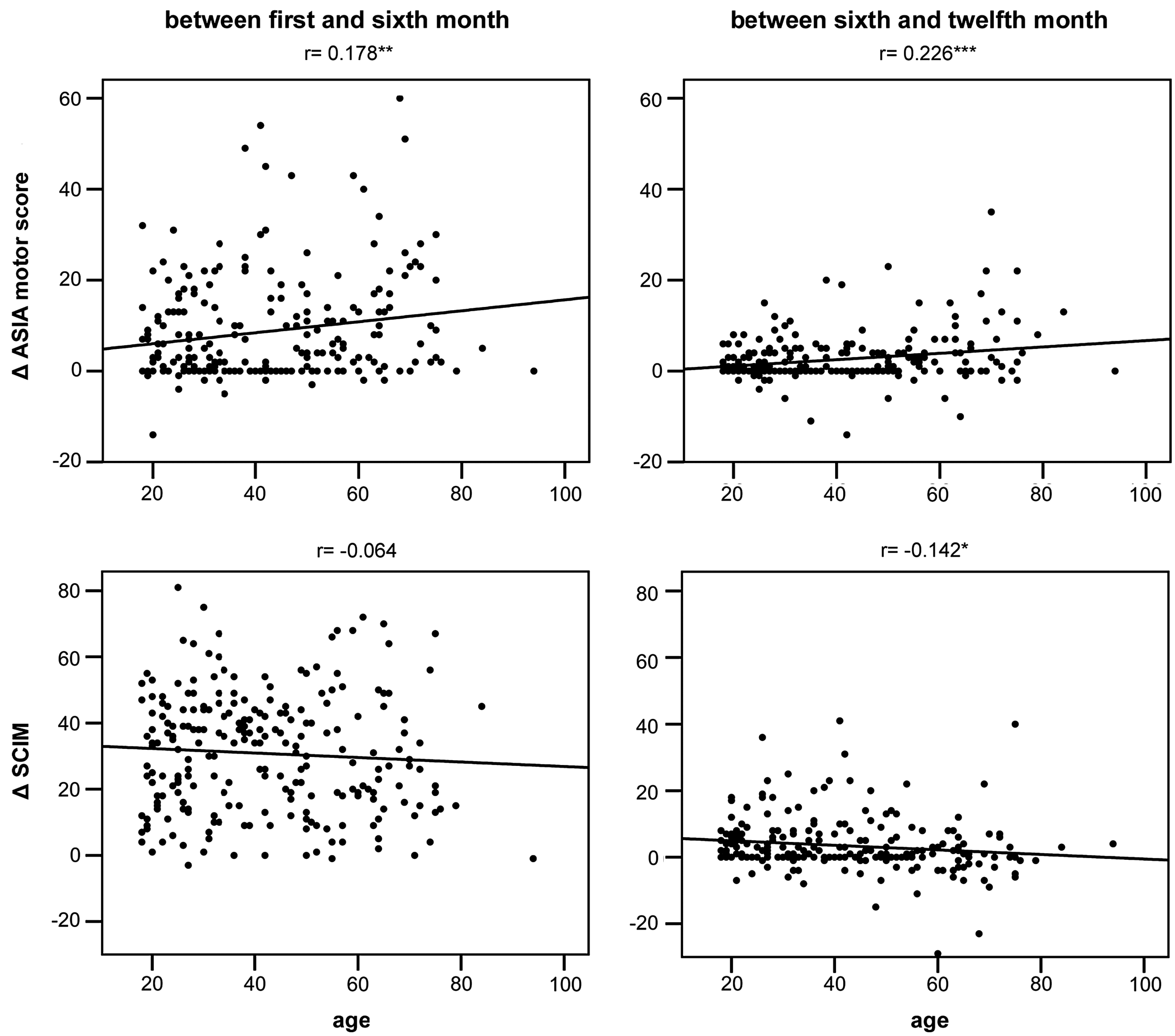

FIG. 1. Correlations between age and changes in ASIA motor score and SCIM (Spinal Cord Independence Measure) for the whole sample for the assessment period between the first and sixth month, and the sixth and twelfth month, respectively. Level of significance: $*p \leq 0.05$; $**p \leq 0.01$; $***p \leq 0.001$.

There was no relationship between age and the duration of inpatient rehabilitation.

Sample characteristics

Compared to a recent literature survey (Wyndaele and Wyndaele, 2006), in our study sample 47% of subjects suffered a tetraplegia (in the survey, 33%), 46% had a complete injury (50%), sex distribution (men/women) was 4.2/1 (3.8/1), and the mean age was 42 years (33 years). Thus, our sample was similar to that described in this survey with respect to sex distribution and severity (completeness of lesion). However, in our sample, more patients suffering a tetraplegia were included and the mean age was higher. The latter point might be due to the fact that we included only patients with an age of at least 18 years.

Age effects on neurological and functional recovery

Surprisingly, for an improvement of the neurological deficit we found a *positive* relationship with age (i.e., older patients showed a greater improvement). At the examination 1 month after injury, the ASIA motor score was not related to age. That means older patients did not have lower scores at the beginning of the rehabilitation than those of the younger patients. In such a case the greater increase during the first year could be explained by a lower starting point. However, after 6 months, the ASIA motor score was positively related to age. In the second half year, one might have expected less neurological recovery due to ceiling effects. However, the positive relationship was even more pronounced at this later stage. Obviously, elderly SCI subjects show a *better* recovery of motor deficit. At first glance this finding is unexpected, but it might be explained by physiological mechanisms similar to those underlying the "ischemic preconditioning" of transient ischemic attacks (TIA) in stroke subjects (Moncayo et al., 2000). The latter study suggests that TIA in elderly subjects cause neuroprotective mechanisms to be induced on a cellular level. This makes the overall damage in the case of a stroke smaller. In our study, subjects with SCI of ischemic origin were not included and data about the existence, frequency, and distribution of ischemic events were not available for our sample. Nevertheless it may be reasonable to argue that ischemic events not directly related to the trauma are more common among the older than the younger SCI subjects within our sample. Since post-traumatic ischemia plays an important role as a secondary lesion mechanism after SCI (Tator and Fehlings, 1991), such neuroprotective mechanisms might also play a role in our older subjects.

Although there was a good recovery of neurological deficit in elderly subjects, no corresponding functional improvement could be detected. In contrast, mostly a negative relationship between age and one of the functional measures (SCIM score or gait speed) was found. Especially within the group of motor complete paraplegia, age was negatively related to SCIM. This corresponds to observations indicating that the functional outcome at discharge is age-related in individuals with complete paraplegia (Yarkony et al., 1988).

The fact that only motor incomplete groups showed an age effect on gait speed might be explained by the fact that only a few patients in the motor complete groups showed any ambulatory function.

Translation of neurological recovery to function

The less favorable functional improvement of older patients can hardly be explained by the course of neurological deficit in the same time period. We suggest that the neurological recovery is not directly related to the functional outcome and that elderly patients have difficulties in translating neurological recovery into positive functional changes. As a consequence, we propose that rehabilitation efforts in elderly SCI subjects should focus on the training of activities of daily living.

Long-term effects

Little data are available on how the functional improvement gained during rehabilitation can be maintained over time (McKinley et al., 2003). One of the major advantages of the EM-SCI network approach is that patients become monitored over a period of 1 year. In this study inpatient rehabilitation lasted usually less than half a year and was not influenced by age. We can presume that the improvements gained in ASIA motor score, SCIM, and gait speed during the second half year occurred mainly after the patients were discharged from the rehabilitation center. While the effect of age on changes in ASIA motor score in the second half year was small but positive, the correlation with changes in SCIM was negative. Older patients obviously have difficulties in applying the condition achieved during rehabilitation into their daily life after discharge. One explanation might be that at home (or at the nursing home), older patients are more assisted during daily life activities than may be necessary. With such “overprotection,” patients might not be sufficiently motivated to apply what they have learned during rehabilitation.

Comparison with corresponding studies

Our findings stand in partial contrast to previous studies (McKinley et al., 2003; Scivoletto et al., 2003), showing a negative age effect on both functional *and* neurological outcome. In one of these studies (Scivoletto et al., 2003), traumatic and non-traumatic SCI subjects were separated into two age groups (under and over 50 years) with matched cohorts to control for level, severity, etiology, and time from injury. The increase in the ASIA motor score was significantly greater in the younger than in the older subject group ($p < 0.001$). The discrepancy regarding the age effect on neurological outcome compared to our study might be explained by the late first examination (due to the long interval from lesion to admission being $57 \pm$ (SD 44) days in our study). A large part of the neurological recovery could have happened before this initial examination. A second explanation could be that there was only a negative age effect on neurological outcome in non-traumatic SCI subjects. Finally, selection bias (described in the section Study Limitations) might be an explanation for the discrepancy.

In the other study (McKinley et al., 2003) with matched cohort analyses of traumatic tetraplegic SCI subjects, a negative relationship between age groups and change in ASIA motor score was described. No analogous effect could be found within the paraplegic group or when an unmatched analysis was performed.

In a third study (Aito et al., 2007), 87 patients suffering traumatic central cord syndrome were examined at discharge from inpatient rehabilitation and were followed for at least 18 months later, with highly significant ($p < 0.001$) negative correlations between age and functional and mobility scores being described. These correlations are in line with our study. However, a negative age effect on neurological improvement was found ($p < 0.01$). This difference might be explained by the fact that only a specific subset of traumatic SCI subjects was included in this previous study.

Study limitations

This study includes some limitations that are potential sources of bias. Some of the following results should, therefore, be analyzed with caution due to the lack of adjustments.

First, from 750 eligible patients we could include only 237 subjects into our analysis. The remainder had incomplete records. The comparison of the available data showed that the excluded patients were older and that the proportion of motor incomplete patients that were excluded was higher: (1) The older age of subjects who could not be included might be due to the fact that these patients suffered severe age-related problems and that their health status prevented their attendance at the follow-up measurement. Thus our sample might have included a bias towards better functioning subjects. This could have influenced the positive relationship observed between age and change in motor score and also for the daily life activities assessed by the SCIM. (2) The inclusion of a higher proportion of incomplete SCI subjects would have resulted in greater changes because spontaneous recovery is predominantly seen in this type of SCI.

Secondly, inherent in the retrospective nature of this analysis is the issue that not all potential confounders were controlled. The influences of race, spinal cord syndromes, preexisting co-morbidities, or type of management in the acute care (e.g., surgical vs. conservative, use of corticosteroids) were either not assessed or not controlled in the analyses.

In European countries no typical countries of immigration exist, so race diversity has less impact compared to that found in the United States and hence race was not assessed in the

EM-SCI study. Subjects with pre-existing morbidities like dementia or polyneuropathy were excluded. Other age-related disabilities were not assessed.

Our sample as a whole comprised a similar male-female ratio as described elsewhere (Wyndaele and Wyndaele, 2006). However, within the subgroup of patients with motor incomplete tetraplegia, a smaller proportion of female subjects was included. Since there might be a difference in the aging process between male and female subjects, our result may be biased and applicable only with caution to the population of female SCI subjects.

Third, gait speed was assessed by the 10MWT. Only a small proportion of the SCI subjects with a motor complete lesion achieved some ability to walk (0.7% at 1 month, 6.7% at 3 months, and 10.2% at 12 months). Considerably more SCI subjects with an incomplete lesion regained walking ability (51.8% at 1 month, 77.2% at 3 months, and 82.6% at 12 months). With regards to the correlation between age and the 10MWT, a floor effect was unlikely to have influenced the results at the 1-month interval, as the non-ambulatory SCI subjects were of all ages. However, at 6 and 12 months, a floor effect might have influenced this relationship, especially in the SCI subjects with an incomplete paraplegia, as the non-ambulatory patients were almost exclusively of a higher age.

Fourth, many of the correlations between age and the improvement of the outcome measurements revealed non-significant associations. This might be explained by the fact that a true association did not exist or that the sample sizes were too small and a true association was rejected due to a type II error. The inspection of the non-significant correlation coefficients showed values that were in a small to insubstantial range ($r < 0.3$; Cohen, 1988). In order to assure that a type II error can be excluded, these small values have to be tested in a sample of appropriate size. Our smallest subgroup (i.e., paraplegia motor incomplete, $n = 39$) would require correlation coefficients greater than approximately $r = 0.31$ to become statistically significant. However such a correlation would explain only about 9% of the variance, which we consider to be clinically irrelevant.

Conclusion

The novel finding of this study is that elderly SCI subjects have difficulties in translating an improvement of neurological deficit into function. This effect was even more pronounced after discharge from the rehabilitation center. Therefore, rehabilitation approaches should focus on training of daily living activities and should assure that after discharge patients become motivated to apply what they have acquired.

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Author Disclosure Statement

The authors declare that no competing financial interests exist.

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